Journal of Rural and Community Development

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Citation:
Dundon, L. A., Abkowitz, M., Camp J., & Philip, C. (2018). Assessing impacts to transportation infrastructure from oil and gas extraction in rural communities: A case study in the Mississippi Tuscaloosa Marine Shale oil play. *The Journal of Rural and Community Development*, *13*(2), 16–38.

Publisher:
Rural Development Institute, Brandon University.

Editor:
Dr. Doug Ramsey

ISSN: 1712-8277 © Journal of Rural and Community Development
www.jrcd.ca

Assessing Impacts To Transportation Infrastructure from Oil and Gas Extraction in Rural Communities: A Case Study in the Mississippi Tuscaloosa Marine Shale Oil Play

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Abstract

Recent advances in technologies associated with hydraulic fracturing and horizontal drilling have provided access to vast reserves of oil and gas that were previously uneconomical to produce, and in areas without a history of concentrated drilling activity. Townships and counties without sufficient financial resources have faced new challenges to maintain transportation infrastructure despite unprecedented volumes of heavy truck traffic on aging roads not designed for such use. Many studies have evaluated the impact of oil and gas development on roads, but small, local communities—where road impacts are felt the most—do not have the resources to utilize much of this information or conduct the necessary advanced data-gathering and analysis. Using the Tuscaloosa Marine Shale (TMS) oil play in Mississippi as a case study, this paper presents a methodology for local planners to identify at-risk infrastructure. By using data obtainable by local planners, we demonstrate how to identify routes likely to be impacted and how to obtain and use data on water volume use, which correlates directly to road impacts and has been underutilized as a component for future planning. This paper also fills a gap by including operator perspectives on local approaches to addressing road impacts.

ISSN: 1712-8277

Keywords: hydraulic fracturing; road impacts; rural economic development; FracFocus; operator perspectives; Mississippi

1.0 Introduction

Oil and gas, like other rural resource sectors, differ from more traditional manufacturing businesses because of the decentralized location of the source of the economic activity—the well. It is often easier for state legislators to see the benefits of investing in surrounding infrastructure when a sizable factory or similar business moves into a rural area. As a result, many states are more willing to provide local governments with transportation-related grants or financial assistance programs designed to attract 'brick and mortar' businesses. For example, Florida has developed an Economic Development Transportation Fund (the 'Road Fund') which provides up to $3 million to local governments to improve public transportation for a company's new location or expansion (Enterprise Florida, n.d.). The Appalachia Regional Commission (ARC) provides grants for access roads, rail spurs, and dock facilities (Appalachian Regional Commission, 2016) associated with a specific business location. Resource industries like hydrocarbon extraction often do not fit within these types of programs and may not qualify local and rural communities for the funds they need to maintain roads at the level modern oil and gas extraction demands. Indeed, many of these programs assume the impacts to be addressed occur after the manufacturing has begun, but in the case of oil and gas, a substantial portion of the impacts occur before a well begins producing.

Some local officials we interviewed believe the reason for the lack of state financial support for local transportation infrastructure in oil and gas producing communities is the absence of a single business location. Oil and gas wells—and the heavy trucks that service them—tend to be spread out within a county, mostly dotting the rural landscape on private property, often not visible from public roads. This is the case in the Tuscaloosa Marine Shale (TMS) oil play in Mississippi, which does not have a history of the large-scale, high-volume hydraulic fracturing that other communities have experienced, but is well positioned for growth. Accordingly, the TMS provides an important case study with potential to assist other rural communities that may be impacted when oil prices support renewed drilling activity.

In the United States, the roads most negatively impacted by traffic associated with hydraulic fracturing and horizontal drilling are those local and county roads that are outside of the federal or state system. State and federal highways are primarily maintained by a state's department of transportation, generally receive revenue generated by the gas tax and from the federal government, and unlike county and rural roads, are generally built to support the high volume of heavy truck traffic that oil and gas development requires. Accordingly, truck traffic does not damage state roads as significantly as it impacts local roads. This presents a special bind for counties or townships that are responsible for rural roads—counties and rural communities have less money than the state to address maintenance and repair, often do not get a share of the fuel tax that the state receives to provide for roads (or if they do, it is inadequate), and yet their roads are the most severely impacted and far more in need of funding during oil and gas operations.

Drawing from existing literature and the data gathered, we set forth potential strategies that under-funded communities may employ to maintain local road quality when drilling increases in the future, and we identify important underutilized and novel data sources to assess impact potential. We also begin to fill a gap in the literature by including operator perspectives on local approaches to addressing oil and gas related road impacts.

The importance of time cannot be overstated. As Bierling noted, "when the energy sector moves into a new area, the impacts on infrastructure are extremely rapid; years of damage can occur in a few weeks" (Bierling, 2014, p. 11). The current decline in drilling activity across the country presents an ideal opportunity for oil and gas producing localities to assess their approaches to road maintenance and encourage responsible development of petroleum resources while preserving transportation infrastructure.

2.0 Literature Review

Since the beginning of the hydraulic fracturing 'boom' in the early to mid-2000s, researchers have been attempting to address the impacts of oil and gas development on transportation infrastructure and provide assistance to state planners (Muehlenbachs & Krupuick, 2013). For example, Brown, Fossum, Hecht, Dorrington, and McBroom (2013) developed models that could be used with sufficient input data to project traffic growth in an area stemming from well development and population growth. Other work has focused on quantification of pavement and bridge degradation associated with the heavy truck traffic needed during hydraulic fracturing (Upper Great Plains Transport Institute [UGPTI], 2010; Quiroga, Fernando, & Oh, 2012; Prozzi, Prozzi, Grebenschikov, & Banerjee, 2011), and Banarjee, Prozzi, and Prozzi (2012) have related overall truck traffic to specific phases of well development. Some researchers have utilized data regarding road damage and growth to develop a per-well impact fee that planners could use to offset expected damage (RPI Consulting, 2008). Still others have used spatial analysis to route origins of key well inputs to better understand where roads may be impacted and the types of future financial commitments that may be needed on a statewide basis (Bratlien et al., 2014), or to understand how routing of certain well-input materials may be better utilized to prevent road impacts (Gilmore, Hupp, & Glathar, 2014). Hefley et al. (2011) has undertaken a detailed study of the costs to construct and drill a well to better understand the significant investments that oil and gas operators must undertake to bring a well into production.

An important aspect of the work in this area has been to estimate the number of heavy truck trips associated with various stages of oil and gas development, including the hydraulic fracturing and production stages (Belcheff and Associates, 2010; Bratlien et al., 2014; New York State Department of Environmental Conservation, 2015; Abramson, Samaras, Curtright, Litovitz, & Burger, 2014; NTC Consultants, 2011). Studies have also begun to collect information and data regarding how states are currently addressing the oil and gas sector's impact to transportation infrastructure in an effort to develop best practices literature (Bierling, et al., 2014; National Cooperative Highway Research Program, 2015; Randall, 2010).

Most of this work is being done at the state level and intended for state transportation planners; however, Ksaibati (2011) has developed a gravel roads management program within the context of identifying current conditions and needed investment to maintain roads when oil and gas development moves into an area. Huntington and Mason have looked at county and low volume roads, collecting data on maintenance costs and surface conditions in order to quantify potential impacts from oil and gas drilling (Huntington, Pearce, Stroud, Jones, & Ksaibati, 2013; Mason, 1983; Mason, Metyko, & Rowan, 1982). Wilke & Harrell (2011) have summarized potential impacts on low volume local roads and developed methodologies for estimating impacts from energy development. Rahm, Fields, & Farmer (2015) have conducted one of the only studies that provides information regarding local government perspectives on the impacts of oil and gas drilling at the local level. We are aware of no literature that includes the perspective of oil and gas operators on this important issue and this paper begins to fill this gap.

Many of these studies provide important data, impact formulas that quantify the relationship between truck traffic and road degradation, and methodologies to further quantify road impacts. However, implementing many of these methods can require sophisticated initial data on local road conditions using video or other monitoring equipment, or personnel that may not be available in rural communities. Indeed, in many rural communities like Mississippi, there is often just one or a few individuals, in volunteer positions on the County Board of Supervisors that are responsible for addressing county road maintenance. Our work is guided by the understanding that rural planners often do not have the personnel or financial resources to review the literature or undertake advanced methodologies (Wilke & Harrell, 2011).

3.0 Hydraulic Fracturing, Horizontal Drilling and Transportation Impacts

Horizontal—or directional—drilling is a technique in which the drill bit moves vertically through the rock, and then turns to drill laterally through the formation. Horizontal wells can access more of the oil bearing formation than vertical wells from one surface well pad, increasing the well's production and reducing surface area footprint (U.S. Environmental Protection Agency, 2016a). Hydraulic fracturing is a process by which the well is stimulated to increase production and begins after drilling. The process involves pumping a mixture consisting primarily of water and sand, and approximately 0.5–2.0% chemicals, at high pressure down the well to create fractures in the rock where oil or gas is trapped, allowing it to more freely flow or be pumped to the surface for collection (FracFocus.org, n.d.).

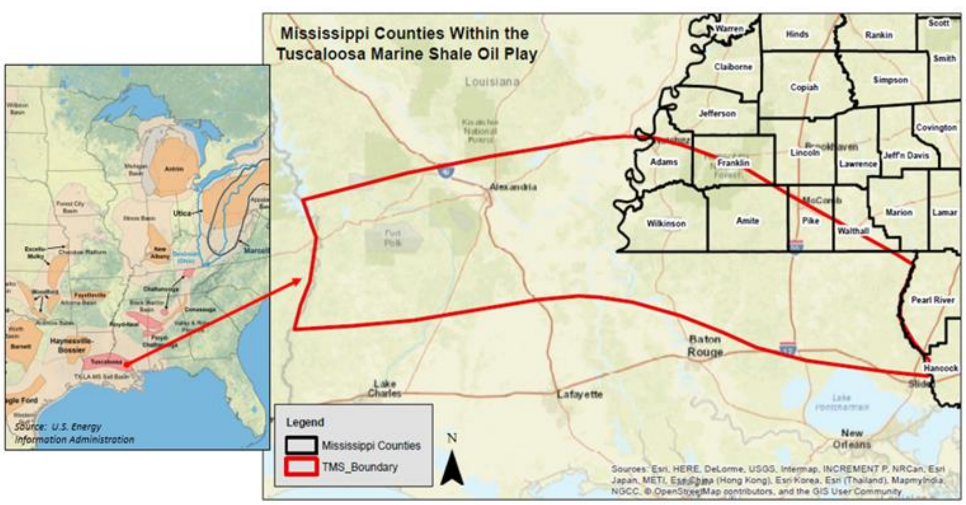
Both horizontal drilling and hydraulic fracturing are old technologies, but together and with recent advances, they have enabled companies to access oil and gas resources that were previously uneconomical to produce, enabling what has been referred to as the "shale revolution" and "one of the landmark events in the 21st century" (Wang, Chen, Jha, & Rogers, 2014, p.1). Advances in these technologies have enabled the United States to become the world's largest producer of oil and natural gas, surpassing both Russia and Saudi Arabia (U.S. Energy Information Administration, 2016).

Hydraulic fracturing and horizontal drilling are necessary components to a continued and robust domestic oil and gas industry, accounting for nearly 80% of new wells drilled in the U.S. as of 2014 (Selley & Sonnenberg, 2014). Well development requires heavy truck traffic to construct, drill, and fracture the well, and to move oil or gas to processing stations and ultimately to market. Road impacts associated with oil and gas development have been studied extensively in recent years, with estimates of 890–2,300 heavy truck trips needed per well (NTC Consultants, 2011; UGPTI, 2010; Bratlien et al, 2014; Quiroga, *et al.*, 2012; Belcheff and Associates, 2010; New York State Department of Environmental Conservation, 2015). Most of the heavy truck trips are compounded to a few weeks or months during the initial well development and hydraulic fracturing phases and tend to decrease during the production phase (Felsburg Holt & Ullevig, 2013). Local and rural roads across the nation were constructed primarily to transport agricultural products, and many oil and gas producing communities have struggled with the rapid deterioration of their infrastructure and inadequate resources to address these new impacts. For example, one study estimated 3,700–4,400 truckloads needed *per year* for cattle shipments, which is close to the number of truck trips occurring *over a matter of weeks and months* during some well development (Bai, 2010). .

4.0 The Mississippi Tuscaloosa Marine Shale Oil Play

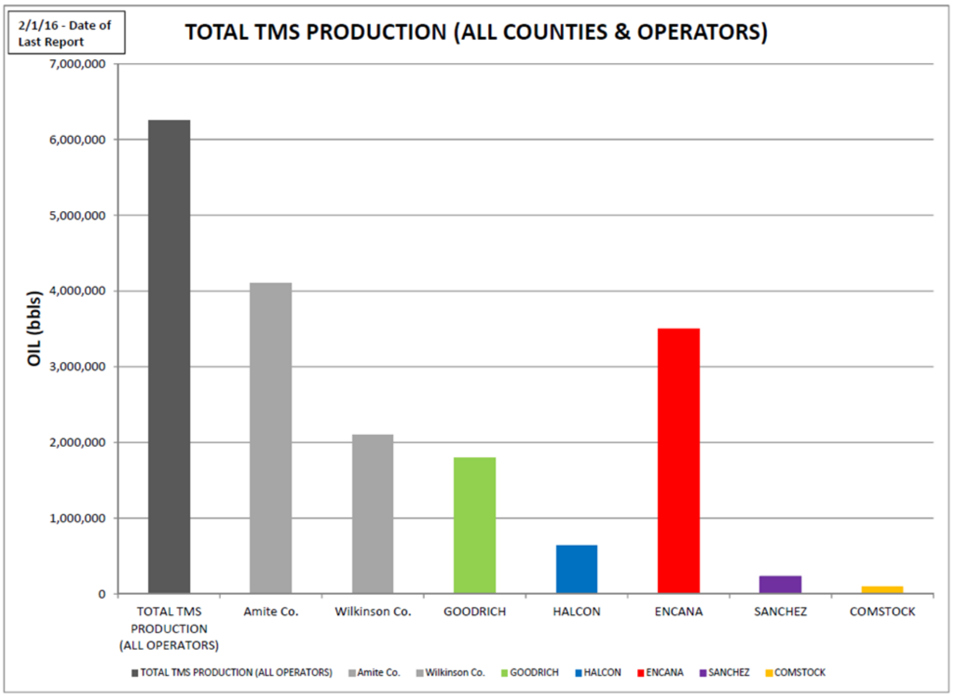
The Mississippi TMS is predominately a tight oil play located mostly in central Louisiana in the United States but also spans several counties in Southwest Mississippi (see Figure 1).

Figure 1. Boundaries of Tuscaloosa Marine Shale (TMS) oil play (red outline) and Mississippi counties within the TMS; inset of TMS location (labeled "Tuscaloosa") near Gulf of Mexico Coast.



An oil or gas 'play' describes a series of oil or gas fields in the same area that share similar geology (e.g., depth). Hydraulic fracturing and horizontal drilling are the key technological factors that have enabled the extraction of economic quantities of oil resources from the TMS. In this paper, we focus on two counties in Mississippi that have experienced a considerable amount of the TMS drilling operations and consequent impacts to roads: Amite County and Wilkinson County. As of February 2016, five oil companies in the Mississippi TMS had produced a total of approximately 6,200,000 barrels of oil, with virtually all of that production occurring in Amite and Wilkinson counties (see Figure 2).

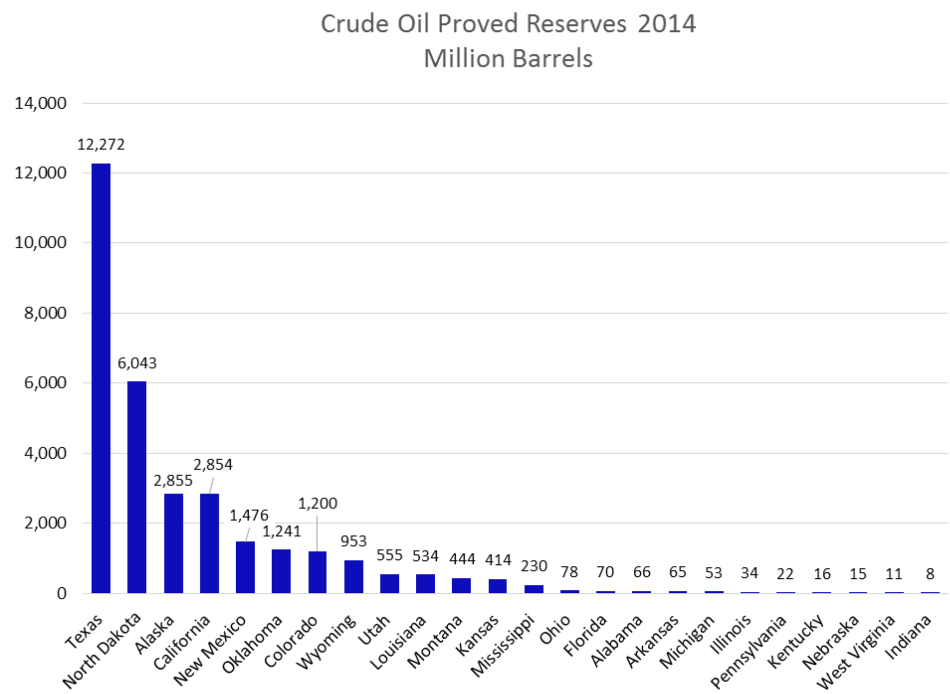
Figure 1. Total Mississippi TMS oil production by county and operator.



Source: Mississippi Oil and Gas Board.

In 2013, the State of Mississippi reduced the severance tax to attract large-scale horizontal drilling in the TMS (Mississippi Code Annotated, 2016), but undertook few major efforts at the state level to pro-actively address the impacts to rural roads that will accompany any significant increase in drilling. Currently, Mississippi's proven reserves of oil are considered small in comparison to other U.S. states (see Figure 3). However, there are studies suggesting that the TMS may hold as many as 7.0–9.1 billion barrels of recoverable oil (John, Jones, Moncrief, Bourgeios, & Harder, 1997; Amelia Resources, 2014), making it larger than the Baaken in North Dakota. Accordingly, the TMS has tremendous growth potential (Chacko, Jones, Harder, & Bourgeois, 2005). Additional converging factors suggest that Mississippi may experience a boom in oil production in the future if oil prices rise sufficiently to support renewed investment. These include the State's attractiveness to oil companies from a barriers perspective, the low severance tax on horizontal wells, and the proximity to major downstream processing facilities. In surveys of petroleum executives, Mississippi has consistently ranked among the most appealing states for investment (Jackson, Green, & Ramsbotton, 2015).

Figure 2. Proven oil reserves by state.



Source: Data compiled from the U.S. Energy Information Administration.

5.0 Methods and Data

To develop an approach to address the gap in the literature with respect to methodologies aimed at underfunded, rural communities, we attended the meetings of the ‘Transportation Pooled Fund Project: State Responses to Energy Sector Developments’, a multi-state effort funded by eight state Departments of Transportation (DOTs), which included meetings between DOT representatives from Montana, Pennsylvania, Ohio, Texas, North Dakota, Louisiana, Washington, and California (Transportation Pooled Fund Program, 2015). We also conducted follow up interviews with several of these states.

Additionally, we interviewed local property owners in the Mississippi TMS with leased wells on their land, and local officials in Pike, Amite, and Wilkinson counties. The selected counties included Pike County, despite the lack of major TMS oil production there, because its roads are impacted by neighboring counties’ oil development. We contacted members of the County Boards of Supervisors with responsibility for roads, attorney advisors to the Board of Supervisors, port officials, and county economic development authorities. Data and information were obtained from the Mississippi Oil and Gas Board (MSOGB), and we interviewed officials from the Mississippi Department of Transportation (MDOT) and the MDOT Office of State Aid Road Construction. We also conducted a small survey of the five oil companies operating in the Mississippi TMS to obtain their perspectives on county approaches to road maintenance. Finally, we mined well-specific data from FracFocus.org on water volume use. All interviewees’ names or positions were kept confidential.

By combining data from these different sources, we developed a methodology that can convey important information about the magnitude and potential locations of transportation impacts from increased drilling, and inform mitigation responses achievable in under-funded communities. By surveying the operators, we also set forth a perspective on road maintenance that has been overlooked in the literature.

5.1 Fresh Water Volumes Used Per Well

The amount of water used in a fracturing job and how that water is transported to and from the well site is the largest predictor of heavy truck trips and consequent road impacts (Belcheff & Associates, 2010). It is therefore important for any community concerned about road impacts to better understand water use. Water data used in the fracturing process is now collected as part of mandatory reporting to FracFocus.org in most oil and gas producing states and voluntary reporting in other states. FracFocus.org is a hydraulic fracturing chemical disclosure registry established to provide the public with information, on a well-by-well basis, of the chemical constituents used in the hydraulic fracturing process. It is in use in approximately twenty-three oil and gas producing states and is under consideration in several others (FracFocus, n.d.). Because FracFocus.org is primarily considered a chemical disclosure reporting site, many transportation planners are not aware that the forms submitted to FracFocus report the total volume of water used to hydraulically fracture each well and can provide an important data source for rural and local planners.

We mined data from FracFocus.org for every available TMS well in Wilkinson and Amite counties. We recorded the water volume used per well by well name, and then compared these with the well names in the data obtained from the MSOGB on currently producing TMS wells to verify the data. Using this process, we verified that fifty-two of the fifty-four TMS wells listed with the MSOGB were also listed on FracFocus.

5.2 Salt Water Disposal Wells

Much of the fresh water used in the hydraulic fracturing process flows back to the surface—called ‘flowback water’. Wells also produce water along with the oil or gas—called ‘produced water’. Flowback and produced water must be disposed of or treated before release to the environment. In the TMS, virtually all of the flowback and produced water is trucked to underground injection wells for disposal, otherwise known as salt water disposal wells (SWDs), which are regulated by the MSOGB. We obtained shapefile data from the MSOGB in order to display the locations of the SWDs in relation to existing or potential future oil wells to enable planners to better identify which rural roads are most likely to be impacted by trucks leaving oil well sites to dispose of water at SWDs.

5.3 Oil Well Locations

The MSOGB maintains data regarding oil wells in the TMS. When Mississippi lowered the severance tax on horizontal wells, the MSOGB segregated data on TMS wells in a database titled ‘Tuscaloosa Marine Shale Oil Pool’.There are few vertical wells that are drilled in the TMS and vertical wells do not produce the substantial truck traffic associated with horizontal wells (NYDEC, 2015). Accordingly, the fifty-four horizontal wells listed by the MSOGB in the Tuscaloosa Marine Shale Oil Pool database can be expected to contain all of the wells of interest in the TMS at the time the data was generated in February 2016.

We converted the TMS well database into a GIS layer. From that larger dataset, we extracted all currently producing wells, all permitted wells, and all wells for which a permit had been obtained but the operator had let the permit expire or it was cancelled—operators have one year to begin well construction from the date of permit issuance.

Currently producing wells have an accurate location—latitude and longitude—that the MSOGB field inspector collects when the well is spudded (when the drill bit enters the ground on its way to the authorized depth); however, permitted wells generally do not have a latitude and longitude associated with the permit application. In the earlier part of this decade, because of the potential oil 'boom' in the area and the rush of permit applications submitted, MSOGB began collecting an estimated latitude and longitude on permit applications. Accordingly, for some permitted wells in the TMS, an approximate location is available. As of the date of our collection of permit data (February 2016), there were 160 actively permitted wells in the TMS, and all but eighteen contain the latitude and longitude. There were 247 wells with cancelled or expired permits, and the majority of those wells (163) do not have an associated latitude or longitude. There are 54 actively producing wells.

Lease activity is generally recognized as a leading indicator of potential future oil and gas growth in an area (U.S. National Park Service, 2008), as is the number of drilling permits issued (Brown, et al., 2013; Wilke & Harrell, 2011). Permit data is more easily accessed by local planners and will provide important information on the number and location of potential well sites.

5.4 Roads and Bridges

To obtain bridge condition data for Wilkinson and Amite counties, we used GIS shapefiles of the National Bridge Inventory (NBI). The NBI ranks bridges according to a rating scale for various bridge elements. Three of these elements, the superstructure, substructure, and deck are the primary structural components of a bridge (Boyce, Hudson, & Burns, 1987), and are most indicative of the ability of the bridge to withstand increased heavy truck loads. The NBI's rating scales for deck, superstructure and substructure conditions are the same (Items 58, 59 and 60 in the NBI elements). If any one of these elements has a low rating, the bridge may be vulnerable if heavy truck loads increase.

The NBI rating scales for superstructure, substructure, and deck are the same and are indicated in Table 1.

Table 1: *National Bridge Inventory Rating Scales for Superstructure, Substructure, and Deck Conditions*

NBI Rating	Rating Description
N	NOT APPLICABLE
9	EXCELLENT CONDITION
8	VERY GOOD CONDITION—no problems noted.
7	GOOD CONDITION—some minor problems.
6	SATISFACTORY CONDITION—structural elements show some minor deterioration.
5	FAIR CONDITION—all primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
4	POOR CONDITION—advanced section loss, deterioration, spalling or scour.
3	SERIOUS CONDITION—loss of section, deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present.
2	CRITICAL CONDITION—advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
1	“IMMINENT" FAILURE CONDITION—major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put it back in light service.
0	FAILED CONDITION—out of service; beyond corrective action

We excluded bridges rated as ‘N’ (which were most often culverts), and by reference to design loads in Item 31 of the NBI, we excluded all bridges in the study area not designed for heavy truck traffic such as pedestrian, railroad, or ‘unknown’ bridges. We then ranked bridges using the lowest of the NBI ratings for deck, superstructure, and substructure conditions for each bridge to obtain a final bridge condition score. We utilized three rating colors for purposes of mapping these bridges and displaying their conditions, as set forth in Table 2. Bridge colors displayed in Figures 5–7 (see Section 6.2, below) correspond to these condition ratings.

Table 2: *Color Display Scale for Final Rating Score*

Bridge Point Color	Range of Final Bridge Condition Score	Condition ratings scale (from NBI)	
Red ●	0–4	0 = failed	5 = fair
Yellow ●	5–6	1 = imminent failure	6 = satisfactory
Green ●	7–9	2 = critical	7 = good
		3 = serious	8 = very good
		4 = poor	9 = excellent

Dividing the bridge conditions into three color-coded rating levels allows planners to more easily assess priorities, and we chose division points that would accurately reflect the level of risk presented by the bridge if heavy truck traffic substantially increased. Bridges that ranked below ‘Fair’ (score of 4 or lower) could reasonably be assumed to be at the highest risk of impacts if major increases in heavy truck traffic occurred and should therefore generally be given priority by planners. Bridges ranked ‘good’ or better (score of 7 and above) generally could be expected to have a greater ability to withstand increased truck traffic. Bridges colored yellow (scores of 5–6) are considered ‘fair’ or ‘satisfactory’ and fall within an area of caution if truck traffic increased.

For road data, we interviewed members of the MDOT and MDOT’s Office of State Aid Road Construction, which provides funding for some county roads. We also interviewed county government officials in Wilkinson, Amite, and Pike counties to better understand local funding for road repair and maintenance. We obtained road functional class data from MDOT in the form of GIS shapefiles which we extracted by county. For Amite and Wilkinson counties, we selected road segments by the entity responsible for maintenance and repair and color-coded these segments to distinguish the responsible county government.

5.5 Operator Survey Data

With the rapid increase in hydraulic fracturing in the early 2010s, many rural communities faced urgent challenges to address road impacts. Road ordinances were one approach that some townships across the United States adopted, including counties in Mississippi. Amite County adopted ‘The Heavy and Oversized Load Regulations Ordinance for the County Roads and Bridges of Amite County, Mississippi’, which took effect July 1, 2014. A gap in the literature exists with respect to operator’s perspectives of the effectiveness of various approaches. Accordingly, we conducted an anonymous survey of oil and gas operators in the Mississippi TMS. The survey was developed using Qualtrics software and a copy of the survey questions and answers appears in Table 3. The survey was sent to all five operators in the Mississippi TMS, which are listed in Figure 2. To protect individuals’ privacy, the survey was anonymous in that no company or individual name was linked to any particular survey response. Prior to sending the survey by email we contacted each company by phone using numbers listed on drilling permits filed with the Mississippi Oil and Gas Board. We were able to personally speak with four of the five companies. The four companies reached by phone indicated a willingness and desire to participate in the survey, but several companies had trouble reaching the correct personnel to prepare the response given the slow-down in drilling in the year prior to the survey, which especially affected drilling in the MS TMS. For example, one company informed us that some of the individuals with the best knowledge for our survey were no longer with the company.

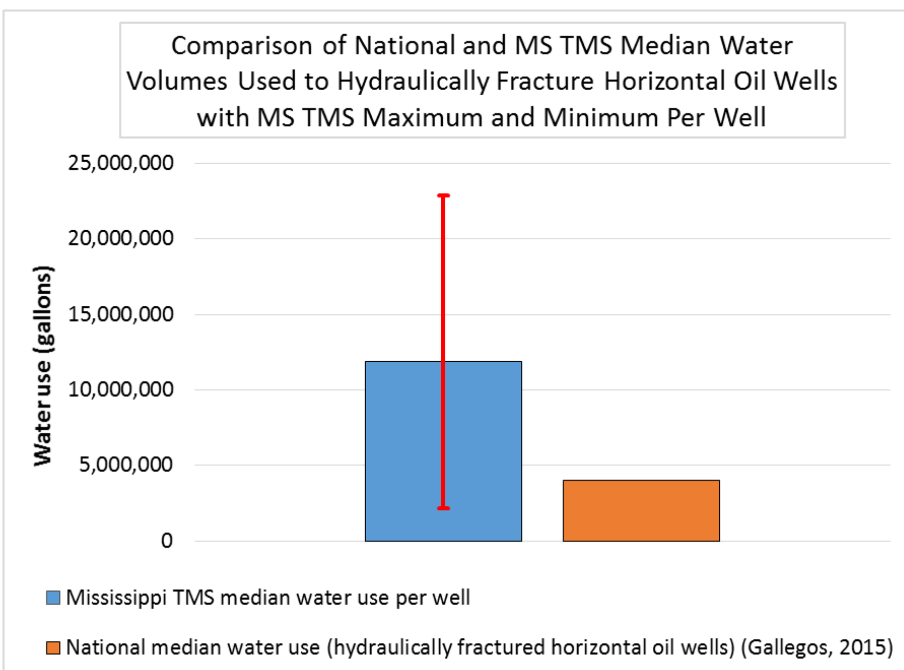
There are only five operators in the TMS, and two of them responded to the survey. As noted, the dramatic slow-down in drilling in the area is likely the reason that only two companies responded, especially because four companies during phone interviews indicated a desire to provide feedback but needed to locate the individuals who had been personally involved in addressing these issues in the local area when the 'boom' in drilling occurred. Although we believe the two companies that responded are likely representative of MS TMS operator perspectives because all the operators share common goals and operations, share utilization of county roads, and are all subject to the same local ordinances, further research regarding operator perspectives across the country is needed.

6.0 Results and Discussion

6.1 Water Volume Used in Hydraulic Fracturing in the MS TMS

One of the most surprising findings of our study is that the water volumes being used in the TMS for hydraulic fracturing are dramatically larger than the national average, which has serious implications for road impacts. A U.S. Environmental Protection Agency (EPA) study concluded that the national median volume of water used during hydraulic fracturing operations at a single well is just over 2.5 million gallons (U.S. Environmental Protection Agency, 2016b), but this estimate includes vertical wells, which typically use less water than horizontal wells. Looking only at hydraulically fractured horizontal oil wells, a recent study found the national median water volume is approximately 4.0 million gallons per well (Gallegos, Varela, Haines, & Engle, 2015). By contrast, we found that the median water volume used to fracture an oil well in the TMS is 11.9 million gallons, nearly three times the national median (see Figure 4). Figure 4 also shows the range between the maximum and minimum volume of water used per well.

Figure 3. Comparison of Median Water Volumes Used to Hydraulically Fracture an Oil Well in the Mississippi TMS and Nationally.



Note: Red bar indicates maximum and minimum water use per well.

This finding is significant because water management practices—such as piping rather than trucking fresh water to well sites—are the most important approach to mitigating road impacts in rural communities, especially where per-well water use is so high. Factors that influence the volume of water needed tend to be local in nature, such as the geology of the formation and the technology used at the well (Kuwayama, Olmstead, & Krupnick, 2015), so this data is especially important to local transportation planners.

Even if all the fresh water used in the fracturing process in the MS TMS is piped to the well—which it is not—EPA estimates that 5–75% of this water will return to the surface as flowback water and must be managed (U.S. Environmental Protection Agency, 2016b). In Mississippi, and in many other states, all of this flowback water is being trucked, along with produced water, to SWD wells for disposal. If only 10% of the median water used in a horizontal TMS fracturing job flows back to the surface for disposal, approximately 1.2 million gallons would be transported in almost 200 tank trucks—assuming 6,000-gallon truck capacity—each weighing upwards of 88,000 pounds over a matter of days or weeks (Wilke & Harrell, 2011).

Water should be one of the first areas assessed to address road impacts and important information is now available from FracFocus, which is not yet being used by transportation planners. Planners could also use the available data to compare water volumes used in emerging plays in their area to existing plays to better anticipate how much additional traffic may be associated with an emerging play as compared to what a community may be already experiencing.

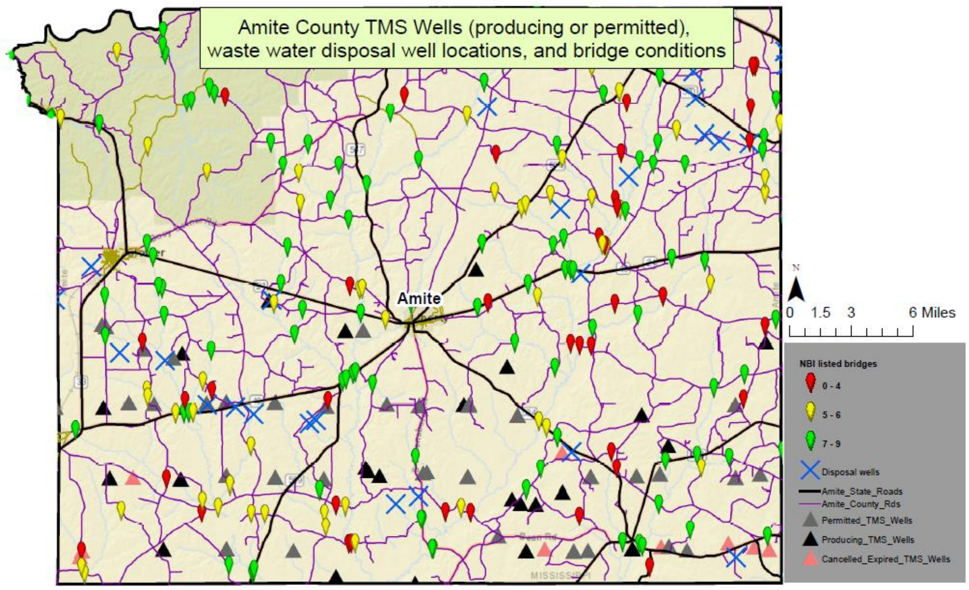
6.2 Methodology to Assess Projected Areas of Impact

Understanding the location of permitted well sites enables a better assessment of which roads may experience increased truck traffic and the potential magnitude of those increases, yet our findings indicate that local planners are often not aware of or utilizing information in this way. Combining spatial data regarding the location of (a) producing and permitted wells, (b) underground injection wells where produced and flowback water from wells will be trucked for disposal (SWDs), and (c) county roads and bridges with indicators of bridge conditions, can quickly inform planners of which road segments or bridges may experience an increase in heavy truck traffic and where more detailed analysis of vulnerability to the increased loads may be warranted.

We assembled these data for both Wilkinson and Amite counties; Figure 5 is an example of the spatial results compiled for Amite County. County roads are indicated in purple and are the responsibility of counties to maintain and repair. State roads are indicated in black and are built to higher standards with more funding for repair.

Figure 5 shows that in Amite County, the vast majority of the prospective, permitted, and currently producing TMS wells are in the southern half of the county. In Wilkinson County (not shown), the southeastern portion of the state has more concentrated well activity—both currently producing wells and potential wells based on the locations of permitted wells. In Amite County, the SWD wells tend to be concentrated in the northeastern and southwestern parts of the county (see Figure 5), whereas in Wilkinson County SWD wells are both more numerous and more dispersed throughout the county, with clusters near the Mississippi River on the western border and in the northeastern part of the county. Accordingly, routing trucks to particular SWD wells may be one method to mitigate road impacts. Planners can also take into account general directional flow of oil and water leaving a well to better understand what routes may be most impacted. Water will be headed to the SWD wells, but oil will often be headed for pipelines, ports, or trucked directly to refineries on the nearby Gulf Coast.

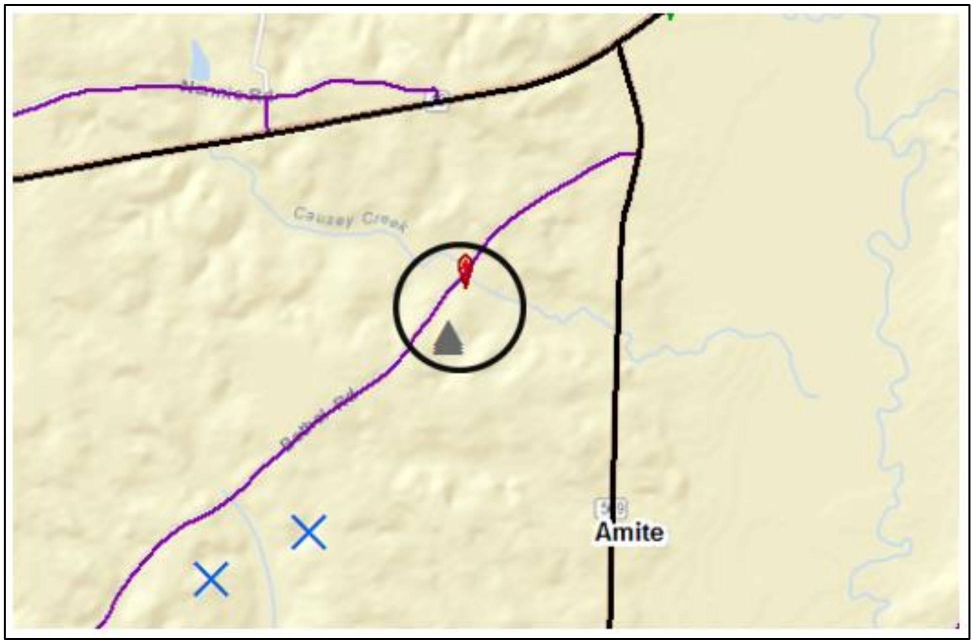
Figure 4. Amite County, Mississippi, Active and Potential Oil Well Sites, Waste Water Disposal Wells, County and State Roads, and Bridge Conditions.



Source: Figure created by author Leah A. Dundon.

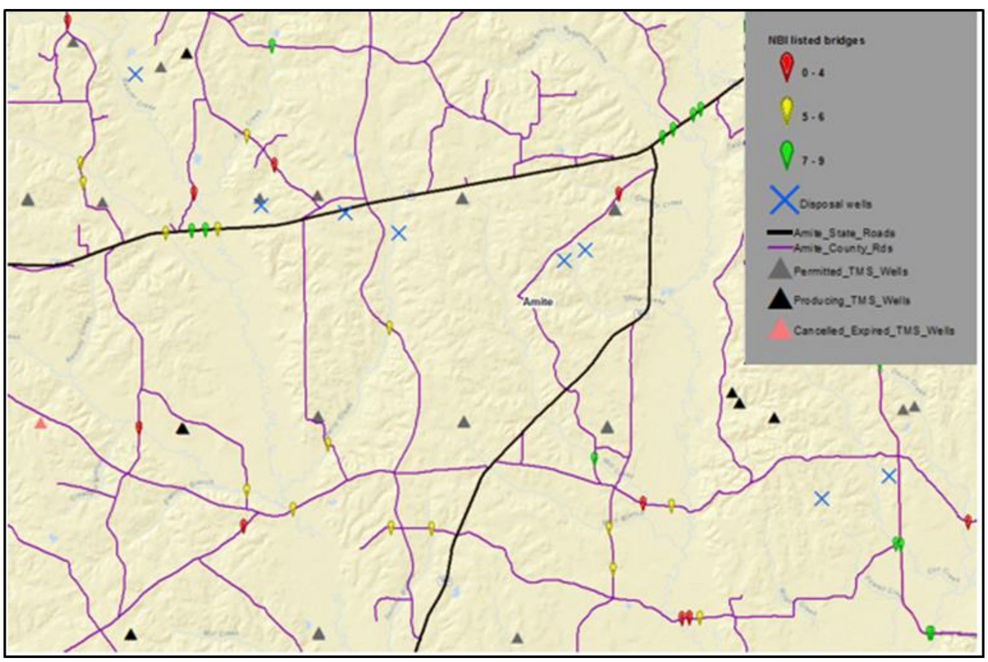
This methodology can also aid in identifying areas where the quickest route to a state road—which operators seek for higher speeds and better roads—is one which involves traversing a bridge that may not be capable of withstanding increased truck loads (see Figure 6), or areas where producing and permitted wells indicate a potential for future growth but coincide with a substantial number of vulnerable bridges (see Figure 7). Planners can quickly extrapolate the damage they may face if each permitted or potential well—denoted by pink or gray triangles—represents an additional 2,000–3,000 heavy trucks on the nearby county roads and bridges. Although, with respect to roads, a baseline assessment of current pavement conditions is an important component of understanding what impact any increase in truck volume will have (New York State Department of Environmental Conservation, 2015; Huntington et al., 2013; Wilke & Harrell, 2011), understanding what routes and bridges are likely to be most impacted is a critical first step that can serve to better direct scarce resources and develop response strategies. If information of well development is communicated from the oil and gas authorities to those with responsibility for local roads early in the process, local and rural planners may have more time to analyze potential impacts to roads around a particular well site and react.

Figure 5. Amite County Prospective Well Locations (gray triangles shown in circle—where shortest route to a state road requires travel over sub-standard bridge).



Source: Figure created by author Leah A. Dundon.

Figure 6. Amite County Area with Significant Numbers of Potential or Already Producing Wells Along County Roads with Numerous Vulnerable Bridges.



Abramson has identified three primary approaches that local governments—city, county, or state—across the country have taken to address impacts to roads from rapid energy development (Abramson, 2014). These include taxation or fees, regulations (e.g., weight limits), or upgrading infrastructure. Amite County, Mississippi adopted a road ordinance which requires a permit for any vehicle loads that weigh greater than 18,000 pounds per axle or with a gross weight over 58,000 pounds. There is no charge for the permit, but it enables county officials to monitor which companies are operating on particular routes, making enforcement easier if there is damage on a road segment. The ordinance requires the operator to inspect the existing conditions of their proposed routes but makes the operator responsible for repairing the road to a passable condition if any permit holder's vehicles cause the road to become impassable or 'weakened', even if the road was already in bad condition (Amite County, Mississippi, Ordinance, 2014). Interestingly, the oil company must conduct or arrange for the repair work, not the county.

Counties and towns across the country have taken similar approaches—National Cooperative Highway Research Program Synthesis 469.

Although there have been a substantial number of studies examining these approaches and their effectiveness from the local, city, or state government perspective, we are aware of no studies or surveys directed to the regulated community—the oil and gas operators that are subject to these approaches. Accordingly, we surveyed the five operators in the MS TMS as to their view of the TMS county road ordinance. The survey questions were open ended and the results are reported in Table 3. Names and any identifying information have been removed to protect privacy. Although only two of the five companies were able to respond to the survey, the results are likely indicative in the area and, although more research is needed, serve as an important first step to including operator perspectives in the literature.

The results reflected in Table 3 were consistent with reports of operator perspectives given by some state DOT representative participants in the Transportation Pooled Fund Project and, although the small response size should be noted, the comments may be considered by planners as approaches to road maintenance are adopted. In many states, operators are willing to pay for the excess damage they cause but are often asked to pay more than what they see is their fair share if the roads were not maintained previously or damage cannot be fairly attributed to their use.

Table 3: *Survey Questions and Responses*

No.	Survey question	Response
1	When significant drilling occurred in the TMS, were local and county road conditions an issue (either positively or negatively) in the counties in which you operate in Mississippi? If yes, please explain in any detail you would like.	**Respondent #1:** Yes, road access is an important issue for our operations. State highways were not a problem as far as current condition and maintenance but permitting new driveway entrances to the well sites was problematic in many cases. The problem was the limit on the number of driveways on a particular tract of land and their distance apart. So, if a home owner had a drive and the oil company wanted to build a separate drive onto the property that may not be allowed. A second problem with permitting is the required line of sight from hills and curves in relationship to the proposed drive. County roads were a big problem for operators. The vast majority of county roads were not designed or built to a very high standard. It seems they were just improved a little bit at a time over the years. The narrow width, lack of a shoulder, low weight bridges, base and top material is all substandard. Heavy truck traffic would damage the roads. The counties would then demand the oil companies, not the timber or other companies, repair the roads or pay for repairs to a much higher level than existed before. Counties have very limited budgets for road maintenance. It was reported to me that the taxes paid from the drilling and production did not fairly come down from the state level to the individual county supervisor. **Respondent #2**: The local and county roads have potholes and minor issues, but they are adequate for drilling TMS activity.
2	Are you satisfied with the approach county governments have taken with respect to road repair and maintenance and are there any different approaches you would recommend?	**Respondent** #1: Mostly unsatisfied. We understand the road systems were not good before the activity. We also understand budgets don't allow significant improvement or repair. For the most part County officials have tried to accommodate road access needs of the operators. But as soon as there is a problem the county demands substantial repair or payment and threatens to pull the permit. The road use ordinance and agreement required to receive a heavy load permit from Amite and Wilkinson County is poorly written. Requires the operator to make repairs to public roads, we do not want to assume that liability. Even distribution of tax income dollars from a well to those roads used for the well. Example: county road budget is divided equally between all districts. Districts with little or no drilling activity receive the same portion as a district with heavy activity.

	Table 2 continued	Support from the State in the form of economic development and distribution of existing tax dollars to upgrade specific county roads. Many county roads were improved over the years by adding a thin layer of asphalt to a gravel road. The local citizens liked this and it handled light duty traffic. This thin layer quickly fell apart under heavy traffic. Even though the local citizens will complain, the asphalt should be removed and these roads converted back to gravel roads which are easily maintained and repaired. In most cases the operators can make due with poor road conditions, even though not ideal we can get in and out. The county government and local citizens will not accept same.
		Respondent #2: No, we are not satisfied with the regulation from the county governments. The Chancery Clerk sent demand letters requiring payment for road damages on county roads on route to drilling locations. The damage estimate included repairing every pothole on the road—regardless of whether it existed prior to our activity. The county used the 'excavate and replace' method to calculate damages; but when the repairs were made, they just filled the potholes which is a much less expensive process and not as long-lasting. On county roads with multiple operator's locations, the demand letters required each company to pay the full cost to repair the road. We attempted to negotiate, but the Chancery Clerk threatened to revoke our right to use county roads if the demands were not paid. On any new jobs, we will require a pre-job survey of all county roads needed to access that job. We will use that survey to contest any future demands from the Chancery Clerk, and to estimate the cost to repair using the counties' excavate and replace method. The estimate to repair all pre-existing damages will be included when evaluating a new well's economics. Hence, the costs for road repairs that are beyond what is fair and reasonable will affect the activity level to the extent that they affect the well economics. We will gladly pay for any damages we caused to county roads, but we are not interested in paying for decades of damages caused by logging and under-investment by the county. There needs to be recourse for the oil company to contest the damage estimate.
3	Would your answers to the previous questions change if there were a substantial 'boom' in drilling in the TMS?	**Respondent #1:** Yes, it would become much worse. If operators are going to be required to pay for county roads used, that will negatively affect the economics of each well drilled. Would the operator have to add an additional million dollars to the cost of a well to pay for a county road to be upgraded and maintained, and how long would that take? **Respondent #2**: No.

7.0 Conclusions

Rural governments could benefit from a spatial analysis that utilizes the locations of permitted and existing wells as a proxy for understanding where development is likely to continue and therefore what routes and bridges may be most vulnerable to increased heavy truck traffic.

Knowledge regarding the volume of water used per well in a locality is especially essential for planners to reduce truck traffic by focusing on water management practices, such as piping fresh water to wells or treating and disposing of waste water on site. FracFocus is a new and important source of data regarding water volumes that local planners should utilize. For underfunded local governments, these are relatively small investments that could provide important benefits.

States—especially poor states such as Mississippi—could be doing more to offset the significant burden to local roads that high volume hydraulic fracturing and horizontal drilling can bring to rural areas. Roads are expensive, and counties are generally not funded sufficiently to maintain roads beyond the 'farm-to-market' types of trucking activity for which their roads were originally designed. Access to well sites is critical for a robust energy sector, and where states seek to encourage responsible development of these resources to promote economic growth, states should direct funding at levels sufficient for counties to provide adequate infrastructure.

One of the most salient factors we observed as to whether a state DOT was satisfied with the approach to local road maintenance in high-drilling areas was the quality of the relationship with industry. In states where the DOT saw the relationship with industry as collaborative, companies appeared more willing to compromise and work with states and towns to assure roads were maintained adequately. States that reported a negative relationship with industry also reported difficulty in maintaining local roads. This finding is based on oral interviews and round table discussions with state DOT participants in the Transportation Pooled Fund Program; however, more work is needed to contribute operator and state DOT perspectives to the literature and better understand synergies between these two stakeholder groups that reduce road impacts and promote responsible development of oil and gas resources.

Acknowledgements

The authors would like to acknowledge financial support from the National Center for Freight & Infrastructure Research and Education (CFIRE), a consortium of University Transportation Centers funded in part by the United States Department of Transportation (USDOT). The authors also wish to express their gratitude to Katie Turnbull with Texas A&M Transportation Institute and all of the participating state departments of transportation in the Transportation Pooled Fund Project: State Responses to Energy Sector Developments (including Pennsylvania, Ohio, Texas, North Dakota, Louisiana, Alaska, Montana, and California), Anna Kuzmich and Lloyd Macadam of the Ohio Department of Transportation, and Kate Nelson of Vanderbilt University. Thanks also goes to David Snodgrass of the Mississippi Oil and Gas Board, Chad Miller of the University of Southern Mississippi, and the residents and local government officials of Pike, Wilkinson, and Amite counties in Mississippi.

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